National Renewable Energy Laboratory
Innovation for Our Energy Future

Energy Diversity

The 26th Pacific Islands Environmental Conference

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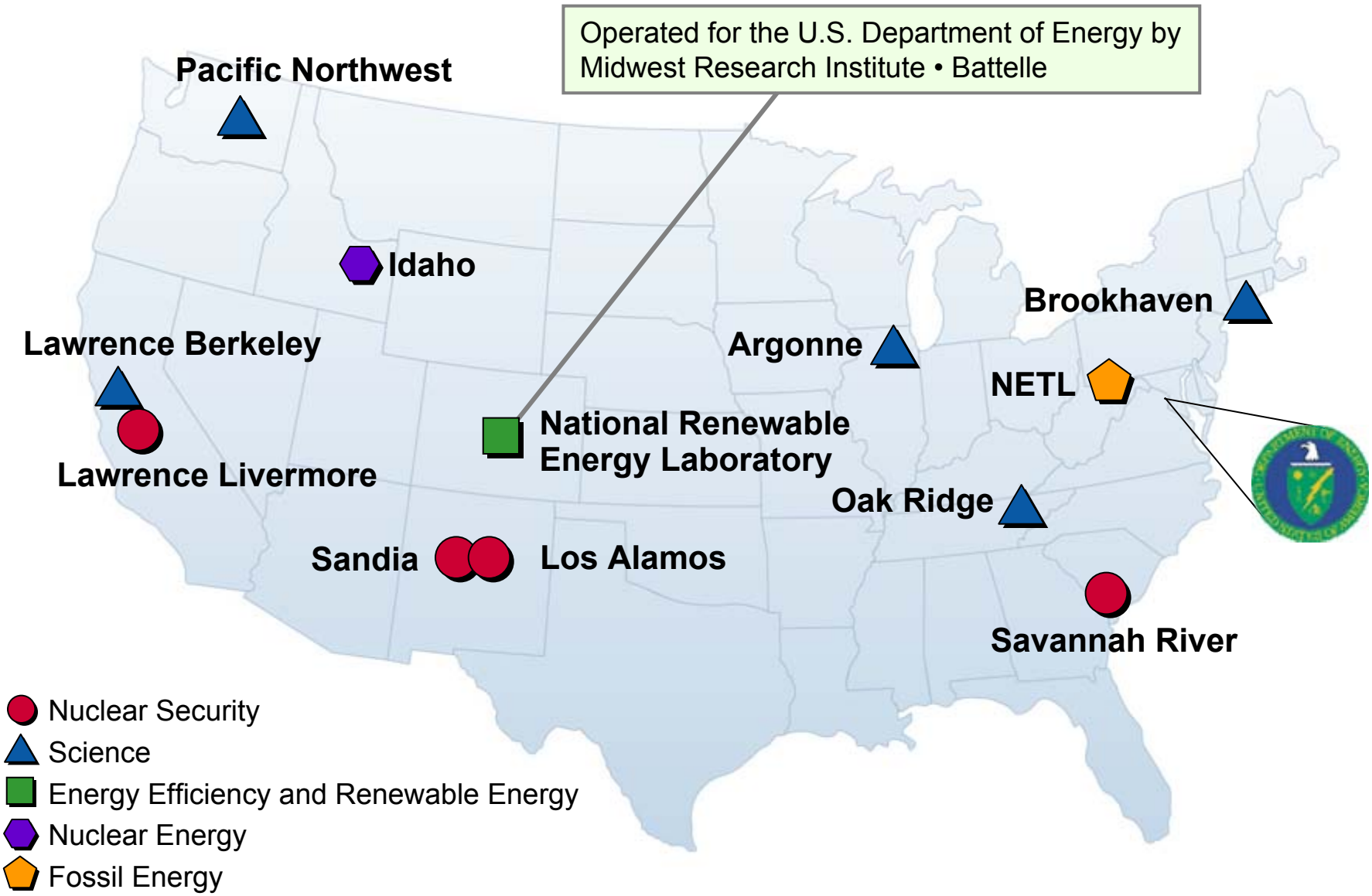
June 2009

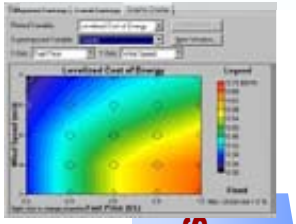
Major DOE National Laboratories



What Makes NREL Unique?

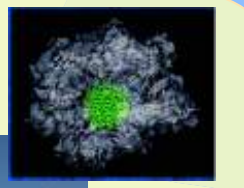
- Only national laboratory whose primary mission is renewable energy and energy efficiency R&D
- Roles span from fundamental science to technology application assistance
- Collaboration with industry and university partners is a hallmark
- Research conducted with a systems and market perspective

World-Class Competencies in Key Areas

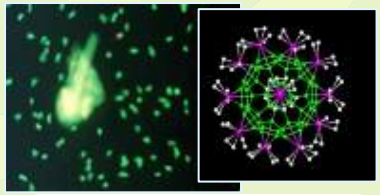


Strategic Energy Analysis

Integrated Energy System Engineering & Testing

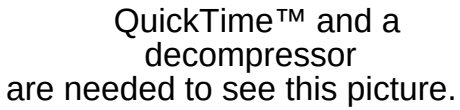


Renewable Electricity Science & Technology



Renewable Fuels Science & Technology

Foundational Science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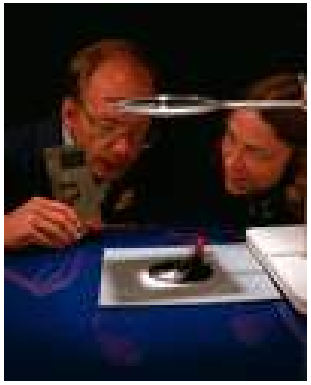
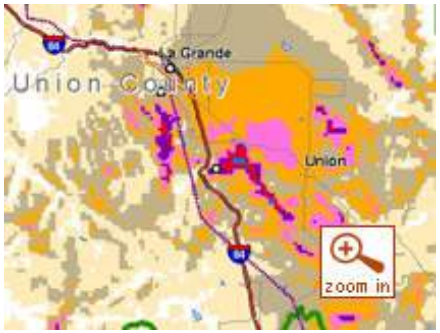
Strategic Energy Applications

Supplier



Co-Development ♦ **Technology Transfer / Technology Maturation** ♦ **Catalyzing Investment**

End User

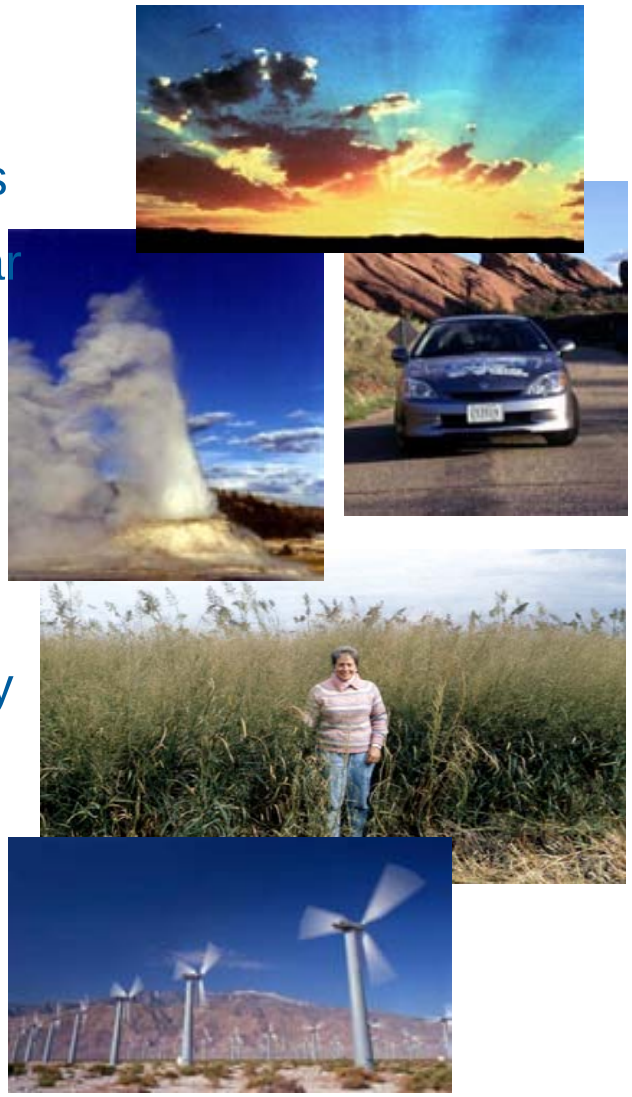


Removing Barriers ♦ **Informing Technology or Policy Decisions** ♦ **Facilitating Energy Projects**

Technology Thrusts

Supply Side

- Wind Energy
- Solar Photovoltaics
- Concentrating Solar Power
- Solar Buildings
- Biomass Power
- Biofuels
- Geothermal Energy
- Hydrogen
- Superconductivity
- Distributed Power



Demand Side

- Hybrid Vehicles
- Fuels Utilization
- Buildings Energy Technology
- Federal Energy Management
- Advanced Industrial Technologies

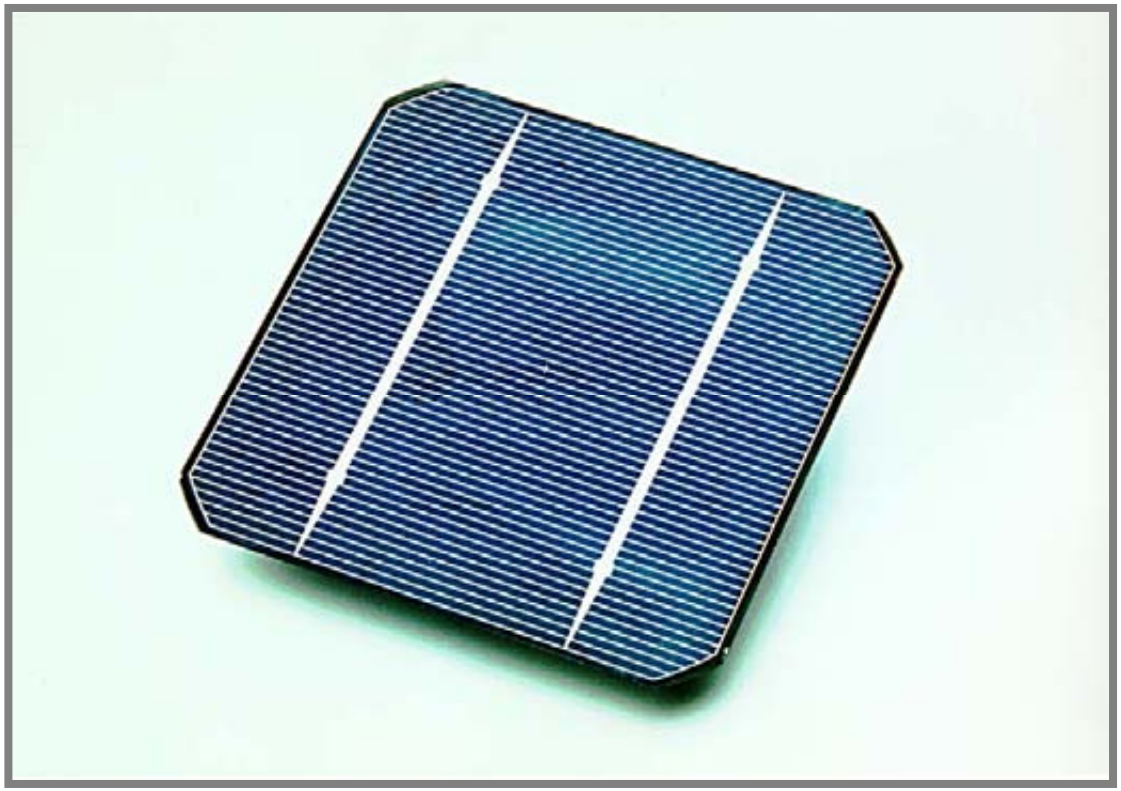
Cross Cutting

- Basic Energy Science
- Analytical Studies
- International
- State, Local & Tribal

Role of Analysis

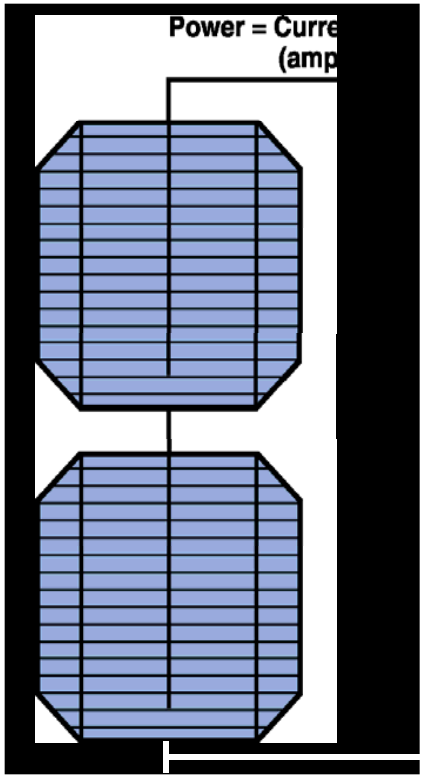
Investing for impact along the concept to commercialization pathway

A typical solar cell (10cm x 10cm) generates about 1W at about 0.5V.

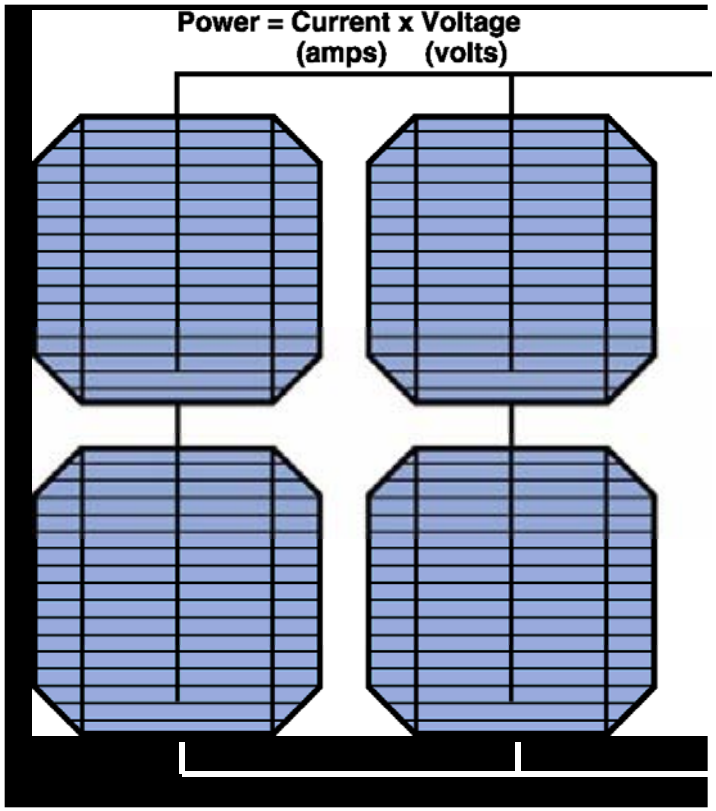


PV Cells

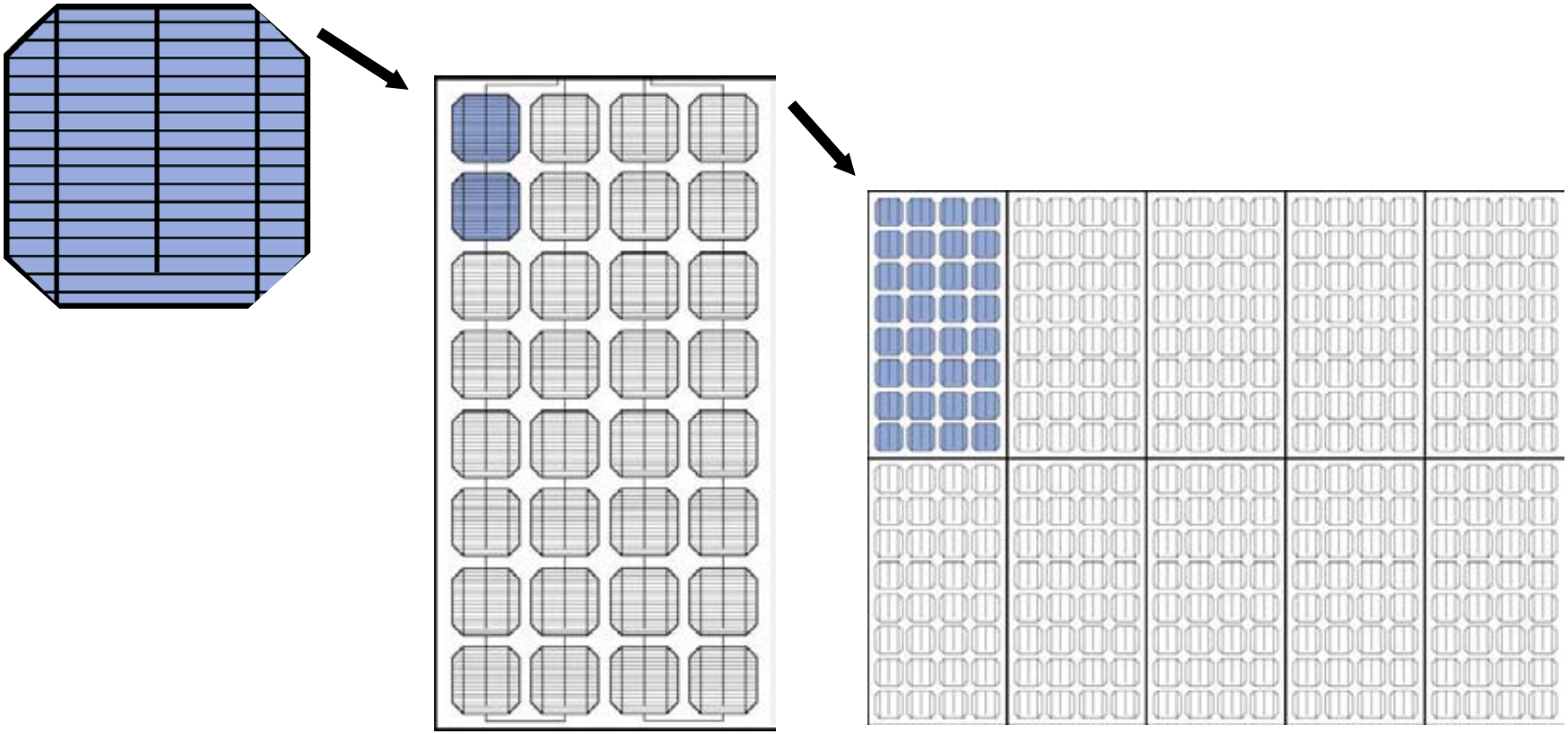
PV Cells are wired in series to increase voltage...



and in parallel to increase current



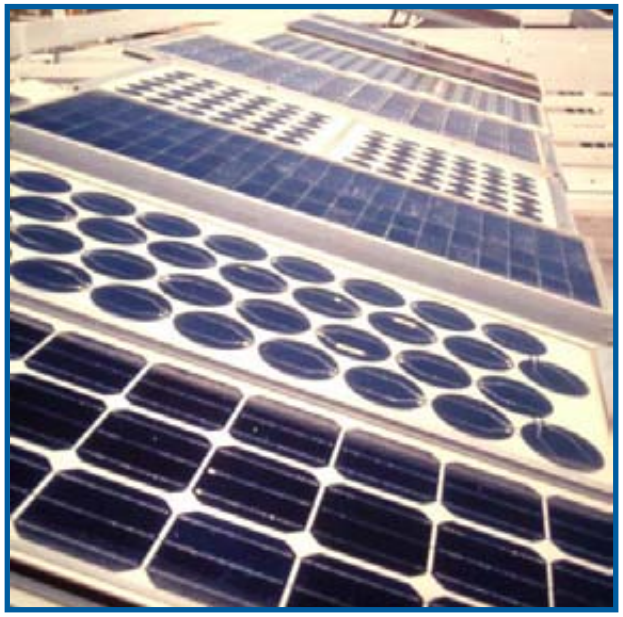
PV is Modular



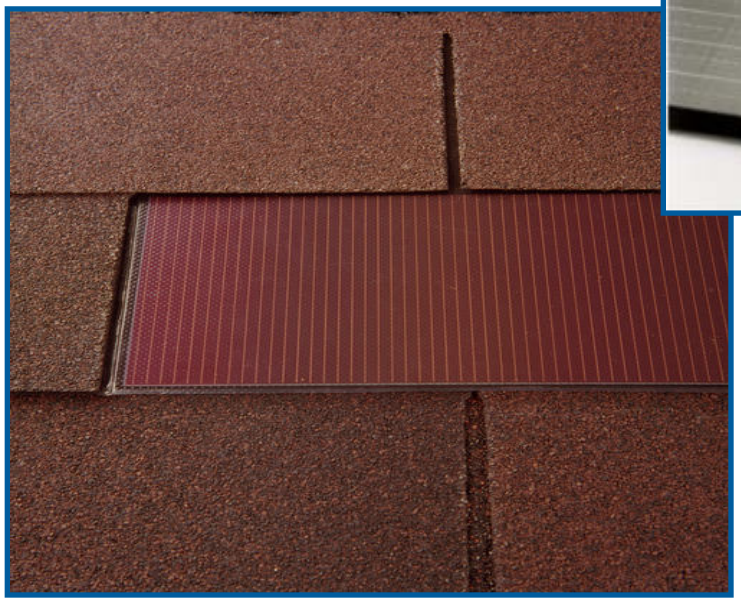
Cells are assembled into modules, and modules into arrays.

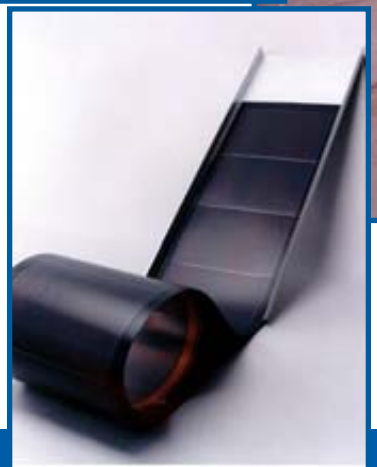
Modules

Individual cells are connected in series (increases the voltage) and in parallel (increases the current) into a module.



Building Integrated PV & Substrates





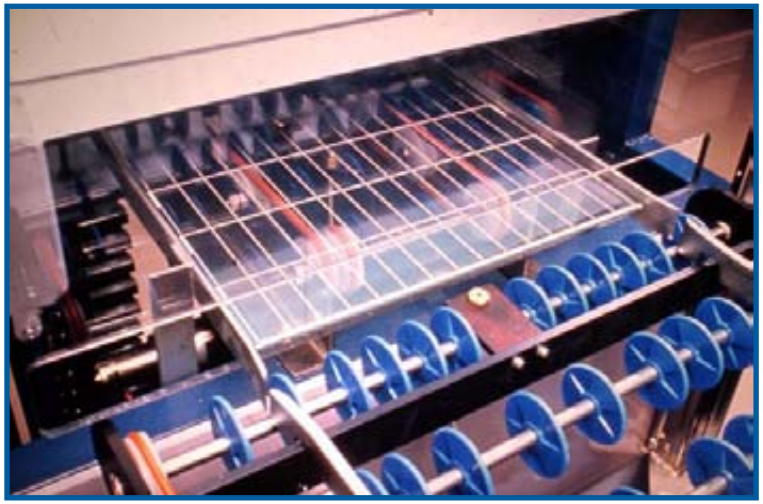
DC PV System Example: PJKK Federal Building, HI

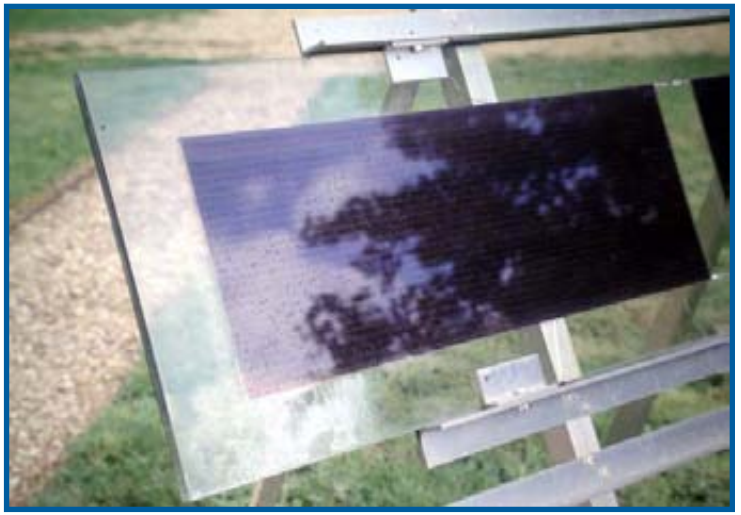
- 2 solar panels per lamp with peak output of 96 watts
- 39 Watt fluorescent lamps, 2500 lumens
- 90 amp-hour battery powers 12 hours per night
- ~$2500 per light

Military Field Applications

USDA Forest Service

Thin Film Technologies On Glass



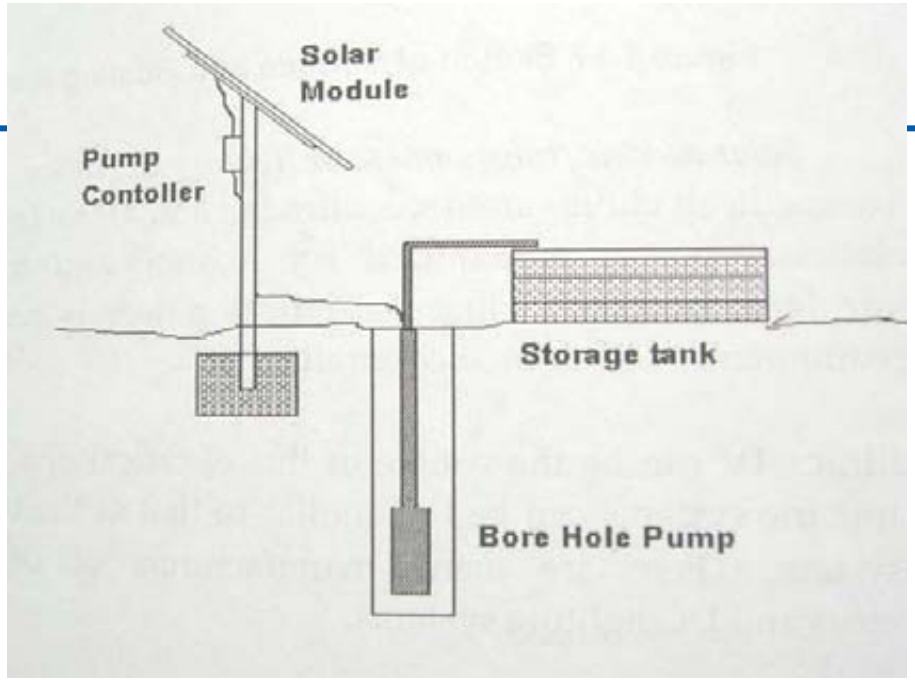


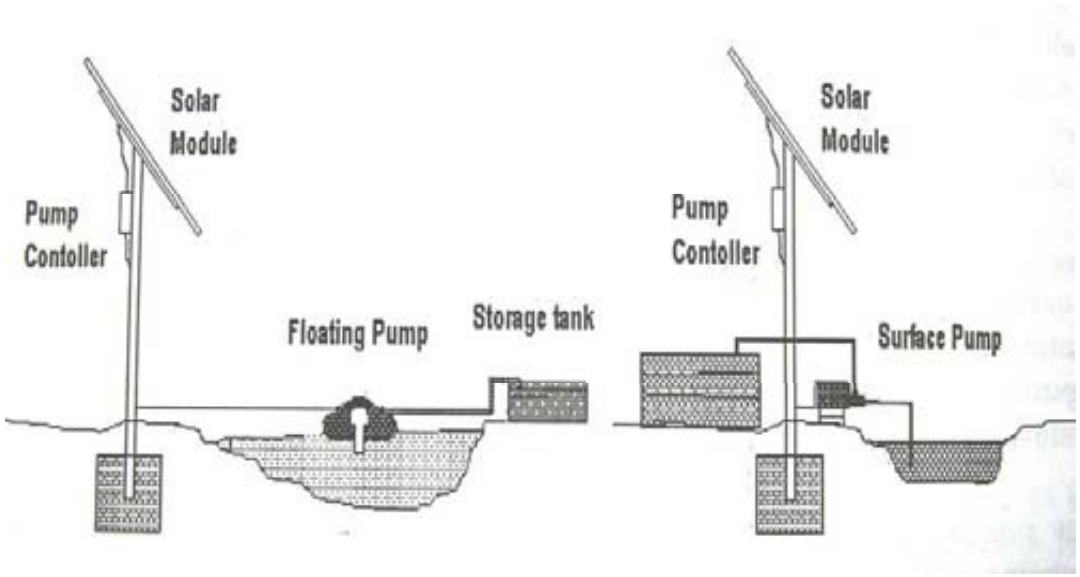
Rural Electrification: Classics

Historically, the primary means of providing power have been through grid extension and diesel generators.

- **Grid Extension:** Very high initial cost, poor cost recovery, time intensive (generation, transmission, distribution) and usually must be subsidized. Most often used.
- **Diesel Generators:** Inexpensive installation but expensive to operate, environmental damage/pollution, and subject to volatile fuel costs and availability.

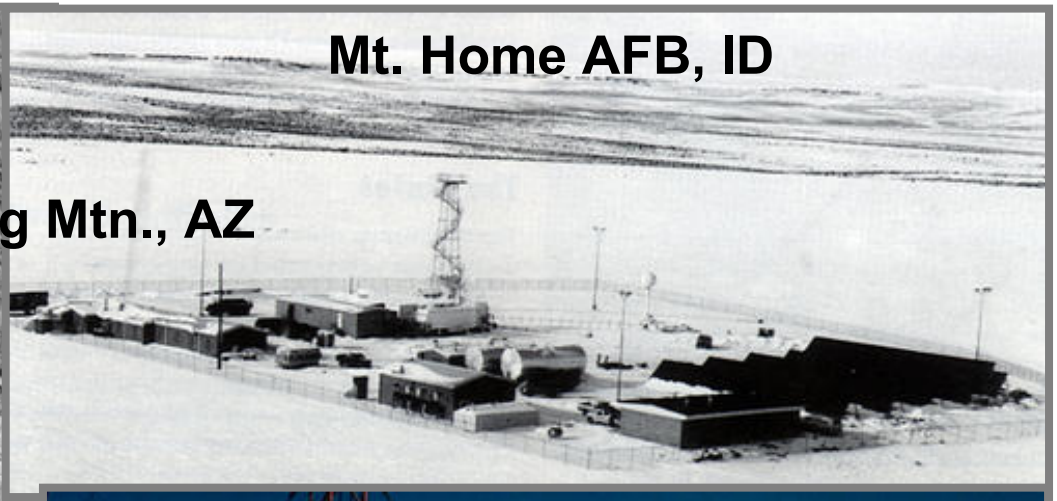
Water Pumping Designs





Hybrid Power Systems are Not New

Carol Spring Mtn., AZ

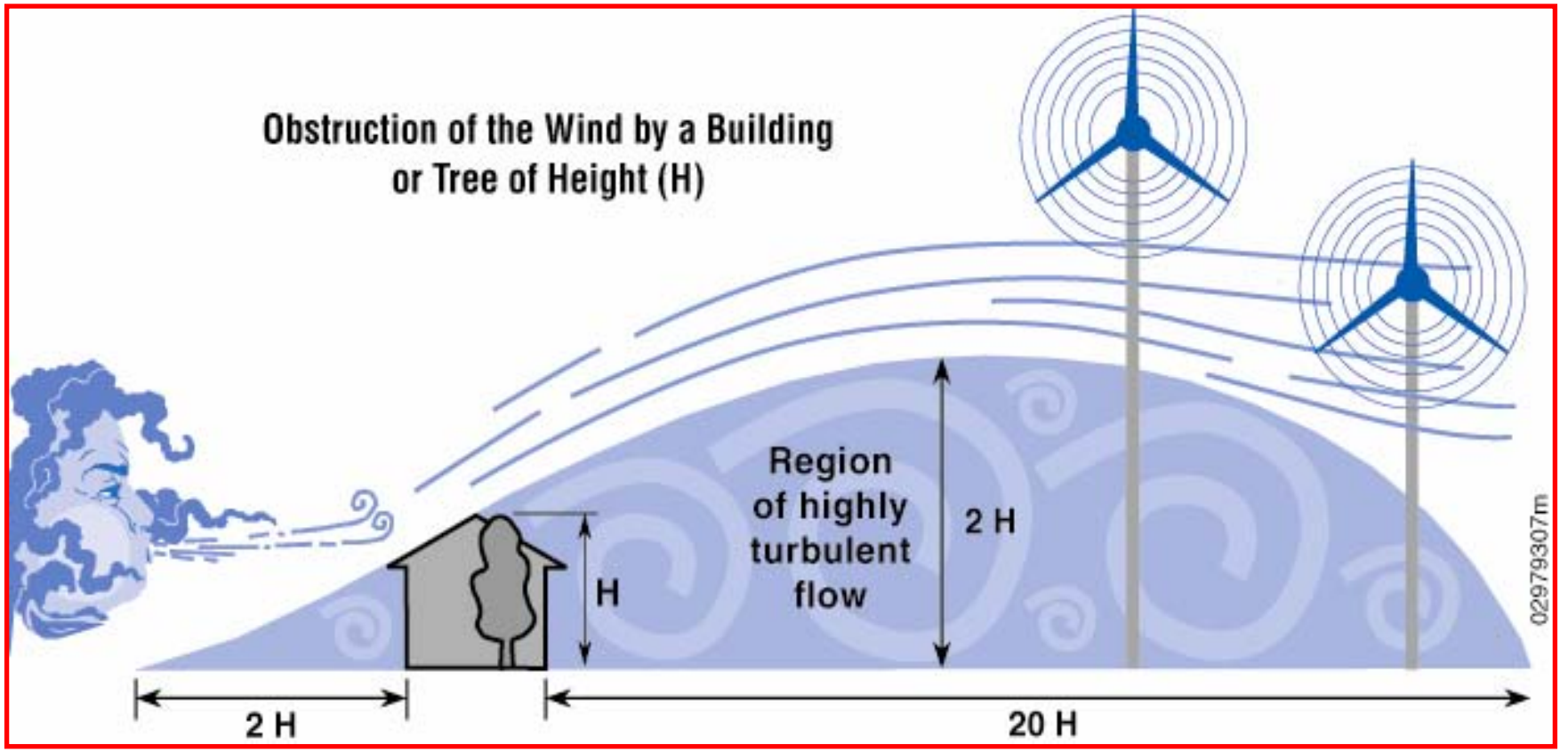


Mt. Home AFB, ID

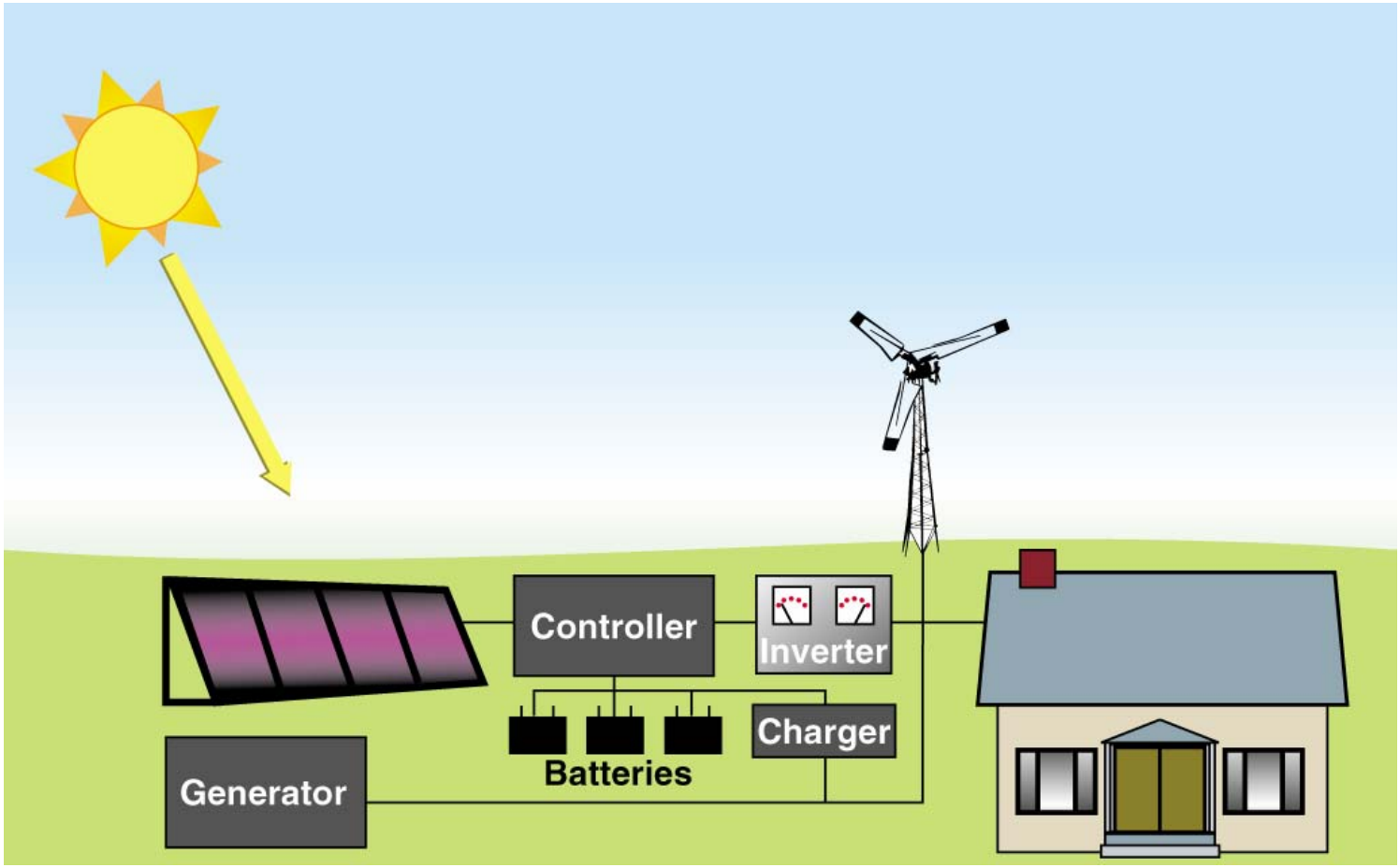
Test Ban Treaty Monitoring, Antarctica

Mt Murdo Station, Antarctica

Importance of “Micro-Siting”



Hybrid PV/Generator System



Hybrid Power Systems

Hybrid power systems use local renewable resources to provide power.

Community hybrid power systems can range in size from small household systems (100 Wh/day) to systems supplying a whole area (10's MWh/day).

They combine many technologies to provide reliable power that is tailored to the local resources and community.

Potential components include: PV, wind, micro-hydro, biomass, batteries, conventional generators, and direct load control.

Agricultural Water Pumping

Livestock watering at the Bledsoe Ranch Colorado, USA

PV, Mechanical wind and diesel backup solves problems with seasonal variations in resource

NEOS Corporation

Home Power Systems

Systems do not have an automated backup generator like most larger hybrids

Very simple architecture:

- Turbine, PV, Disconnects, Batteries
- DC Loads or AC power through an inverter

Primarily PV dominated for small loads, wind has potential at larger loads.

In many instances a combination of PV and wind make most sense

Can vary in size, power output

Single Home Systems/mini-grids

Chipepte, Mexico

- Windseeker 503
- 1000Ah, 12V, “No maintenance” Battery Bank
- < 100W DC Loads

Pez Maya, Mexico

- 2 AIR Marine 403 turbines
- 1000Ah, 12V, “No maintenance” Battery Bank
- 1100W inverter
- power to a small mini-grid for homes and cottages

Pez Maya

Santa Cruz Island, California, USA

Remote Telecommunications station

- Power System
  - PV array
  - Two wind turbines
  - No Backup generator
- Vary costly access/site visits
- Remote operation and monitoring of system

Northern Power Systems

San Juanico, Mexico

Remote fishing & tourism community of 400 people

Power System

17 kW PV

70 kW wind

80 kW diesel generator

100 kW power converter/controller

Advanced monitoring system

Inner Mongolia

Remote Village of Joanes, Brazil

Remote village the Island of Marajo

50kW Power System
- PV array
- Four wind turbines
- Backup generator

Northern Power Systems

Power system used to support local grid

Wind-Diesel Power Systems

- Larger systems with demands over ~ 100 kW peak loads up to many MW
- Based on an AC bus configurations
- Batteries, if used, store power to cover short lulls in wind power
- Both small and large renewable penetration designs available
- Large potential mature with fewer examples
- Provide conventional AC power

Ascension Island

Four NEG-Micon 225 kW turbines installed in 1996.

U.S. Air Force installation on British island in mid-Atlantic ocean.

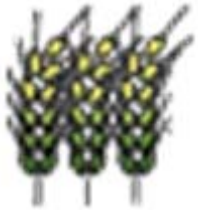
Prime diesel generation with rotary interconnect to British 50 hertz system

Conclusions

- Many options for the configuration of hybrid systems - Depend on load, resource, and costs.
- Medium penetration wind-diesel systems are operating in various isolated locations around the world. Instantaneous wind penetration levels exceeding 50% of load are common.
- Several high penetration systems, with and without energy storage, have been successfully demonstrated.
- High penetration systems are capable of prolonged diesel-off operation.

Resource Assessment

Resource *DATA* → Technology *INFORMATION*



Maps

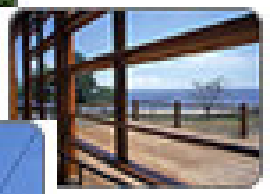
Databases

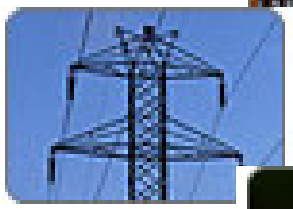
PVWatts

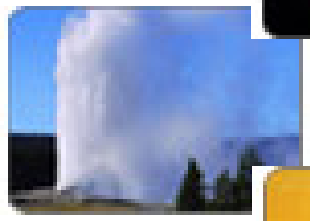
Models

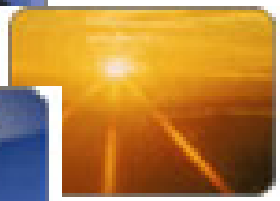
Climate Summaries

Real-Time Data









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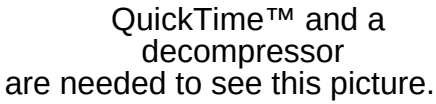
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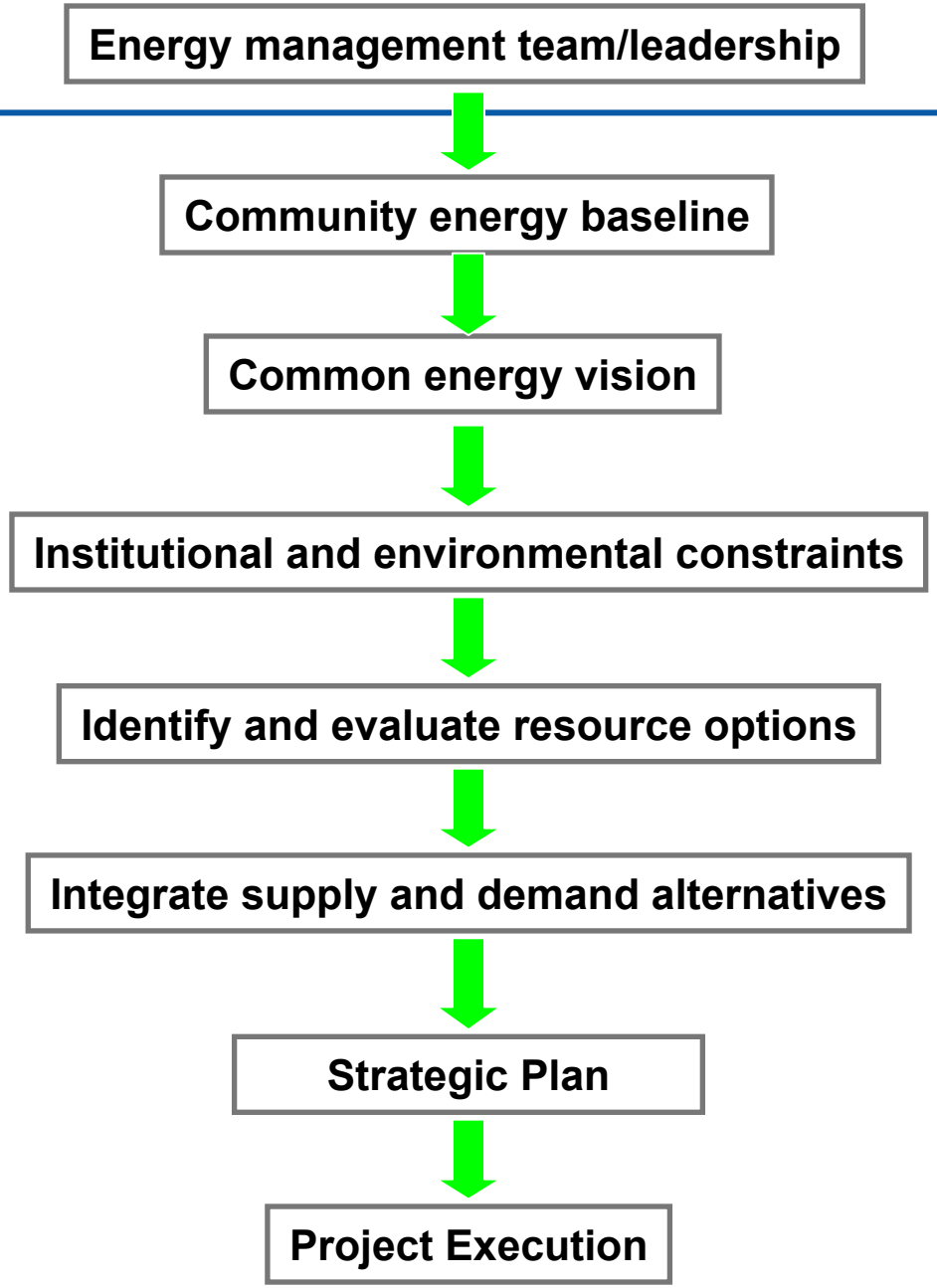
Strategic Energy Planning

Objectives

- Security
- Reliability
- Off-Grid Power
- Environment
- Supply Diversity
- Local Resources
- Economic Development
- Technical Expertise



TAP Our Resources

- Renewable Energy Resource Supply Assessment
- Policy Options and Analysis
- Economic Development
- Sustainable Facility and Community Planning
- Transportation Planning and Alternative-Fuel Options
- Crosscutting Resources

www.eere.energy.gov/wip/resources.cfm

Humanity's ecological footprint, our impact upon the planet, has more than tripled since 1961. It now exceeds the world's ability to regenerate by about 25 percent.

The biggest contribution to our footprint is the way in which we generate and use energy.

The Four C's

- Connect
- Conserve
- Carry Out Energy Efficiency Improvements
- Consider Renewable Energy Systems